Let’s Stop “Mucking Around”: Understanding Wetland Soil Physicochemistry in Relation to Water Quality, Ecosystem Integrity, and Risk Assessment for Wisconsin’s Wetlands and Other Waters




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Acknowledgements

Funding for Fieldwork and Data Analysis:

US EPA Region V

Wetland Program Development Grants

In-Kind Soil Lab Analyses:

WI Soil Science Cooperative Program: Technical Soil Services Project

USDA-NRCS National Soil Science Laboratory (Lincoln, NE)

Field Surveys:

-WDNR Water Quality, Watershed, and Natural Heritage Conservation Bureau Staff

-Ken Thompson (Thompson Soil and Environmental)

Wisconsin Wetlands

> 5.3 Million Acres of Wetlands (probably > 6 Mil. Ac.)

> 50% lost post- European Settlement

36 Recognized WL Plant Community Types!

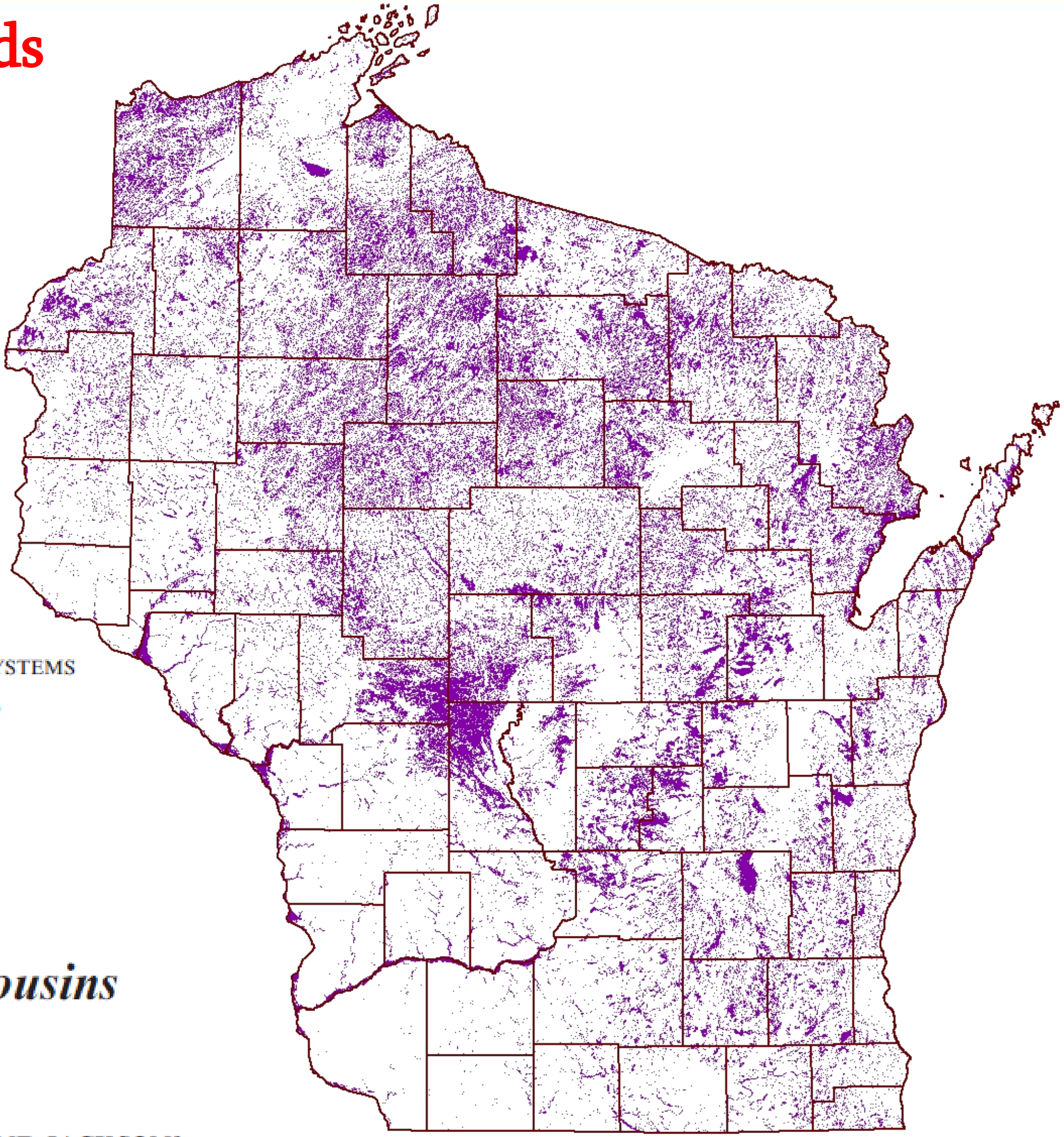
AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS

Aquatic Conserv: Mar. Freshw. Ecosyst. **26**: 892–916 (2016)

Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/aqc.2709

Wetlands: conservation's poor cousins

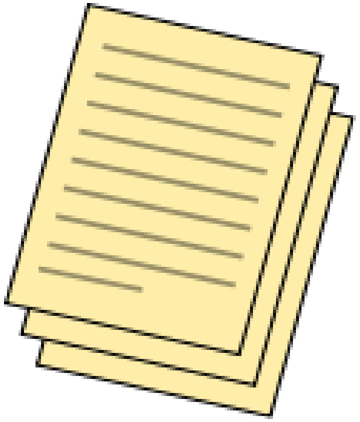
RICHARD T. KINGSFORD[a,*], ALBERTO BASSET[b] and LELAND JACKSON[c]



Wetland Water Quality Standards

Excerpt from WI NR 103.03 (Enacted 1991, Revised 1993)

"To **protect**, **preserve**, **restore** and **enhance** the quality of waters in wetlands and other waters of the state influenced by wetlands, the following **water quality related functional values or uses** of wetlands, within the range of natural variation of the affected wetland, shall be protected…."

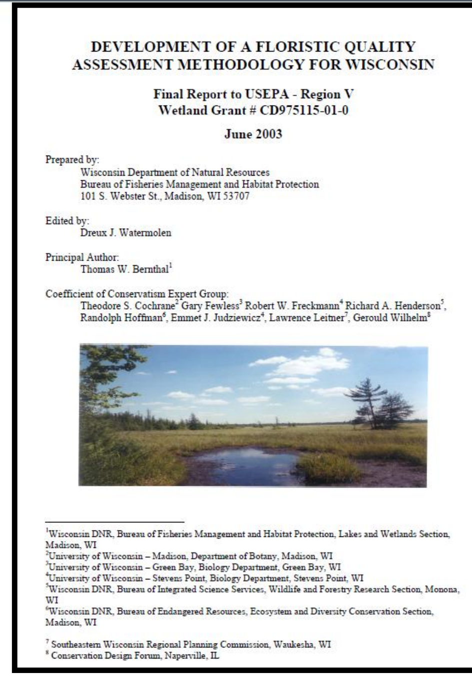


- Storm/Floodwater Storage
- Hydrologic Functions (groundwater recharge/discharge)
- Filtration of sediments, nutrients and toxic substances
- Shoreline protection
- Aquatic habitat (for organisms, and for plants and animals upon which these organisms depend for their needs in all life stages)
- Resident and Transient Wildlife Habitat
- Recreational, cultural, educational, scientific and natural scenic beauty values and uses

Floristic Quality Assessment: 2003→Present

- **Wisconsin Floristic Quality Assessment Method (WFQA)**
  - Coefficients of Conservatism
    - Every Vascular Plant Species
    - Within a Regional Flora (WI = Region)
    - Site Fidelity (Pre-Settlement Remnants)
    - Tolerance of Disturbance
    - Score Range: 0-10
    - Non-natives default to 0

Today: Mean Coefficient of Conservatism
(Average C value of all plant spp. observed)



DEVELOPMENT OF A FLORISTIC QUALITY ASSESSMENT METHODOLOGY FOR WISCONSIN

Final Report to USEPA - Region V
Wetland Grant # CD975115-01-0

June 2003

Prepared by:
Wisconsin Department of Natural Resources
Bureau of Fisheries Management and Habitat Protection
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[5]Wisconsin DNR, Bureau of Integrated Science Services, Wildlife and Forestry Research Section, Monona, WI
[6]Wisconsin DNR, Bureau of Endangered Resources, Ecosystem and Diversity Conservation Section, Madison, WI
[7] Southeastern Wisconsin Regional Planning Commission, Waukesha, WI
[8] Conservation Design Forum, Naperville, IL

Why WFQA?

WETLANDS ASSESSMENT

Wetland Science and Practice (2015)

STATE-OF-THE-SCIENCE REPORT
Trends in Floristic Quality Assessment for Wetland Evaluation

Douglas A. DeBerry[1], Department of Biology/Environmental Science and Policy Program, College of William and Mary, Williamsburg, VA, Sarah J. Chamberlain, Riparia, Pennsylvania State University, University Park, PA, and Jeffrey W. Matthews, Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana-Champaign, Urbana, IL

- "…a non-biased analog for biological integrity in wetlands"
- "…dispassionate, cost effective, and repeatable"

Defining Disturbance Gradient

WISCONSIN DNR
Department of Natural Resources

Wisconsin Floristic Quality Assessment for Wetlands
Disturbance Factors Field Checklist Form WFQA2017

Project: ______________________________

Disturbance Factors Field Checklist

Site Location Information		
Site/Assessment Area Name:	Plant Community Type:	County:
Date: Time:	Observers:	

Hydrological or Habitat Alteration (Stressor):	Stressor	AA (Assess. Area)	30m Buffer	Historic	Impact Level (L, M, H)
Is there a hydrological or habitat alteration present at the site?	Ditch				
Consider each Stressor. Check the box if current stressors are observed in the AA (Assessment Area) or within a 30m Buffer (around the AA).	Tile				
Check the Historic box if a stressor is evident but occurred in the past.	Dike				
Rank the level of impact as L (low), M (medium) or H (high).	Water Control				
	Dredging				
	Filling/grading				
	Excavation				
	Clear/Selective cut*				
	Herb removal				
	Entire Vegetation stratum removal				
	Mowing/Grazing				
	Plowing/Ag				
	Sedimentation				
	StormH20 input				
	Eutrophication				
	Motor vehicle use				
	Road/RR/trails				
	Invasive Animals**				
Buffer (30m): For buffer stressors, note how much of the buffer area was observed and any other explanatory notes.	Buffer Notes:				
Other Stressors or Comments: Note and describe any additional stressors. Make additional comments related to disturbance (this could include how commonly the stressor occurs in the watershed/region of interest.)	Other Stressors or Comments:				
* Tree Age class on next page ** Invasive plants on next page					

Hydrologic (Ditch – Excavation)

Vegetative (Clear/Selective cut* – Plowing/Ag)

Physical/ Chemical (Sedimentation – Invasive Animals**)

Tree Age Class: *Wooded wetlands: Estimate the degree of logging disturbance. Age is approximated by the average size (dbh) of the taller trees. Size is not always a reliable indicator of age. Select only one.*	□ Not applicable □ (1) Seedlings: < 2.5 cm (<1") - Very Recent, Very High Disturbance □ (2) Saplings: 2.5-10cm (1-4") Recent, High Disturbance □ (3) Middle-Age: 10-25 cm (4-10") – Not Recent, Moderate Disturbance □ (4) Mature: >25 cm (>10") – Low Disturbance

% Coverage Invasive Plants¹: *Consider the entire site. List the invasive plants present at the site. What percent of the site is covered by each invasive plant? Select only one coverage class for each plant listed. List additional invasive plants in General Comments if needed.*	Invasive Plant 1:	□ (1) Present: 1% or less aerial cover. □ (2) Sparse: 2-5% aerial cover. □ (3) Medium: 6-25% aerial cover. □ (4) Extensive: 26-50% aerial cover. □ (5) Very Extensive: >50% aerial cover.
	Invasive Plant 2:	□ (1) Present: 1% or less aerial cover. □ (2) Sparse: 2-5% aerial cover. □ (3) Medium: 6-25% aerial cover. □ (4) Extensive: 26-50% aerial cover. □ (5) Very Extensive: >50% aerial cover.
	Invasive Plant 3:	□ (1) Present: 1% or less aerial cover. □ (2) Sparse: 2-5% aerial cover. □ (3) Medium: 6-25% aerial cover. □ (4) Extensive: 26-50% aerial cover. □ (5) Very Extensive: >50% aerial cover.

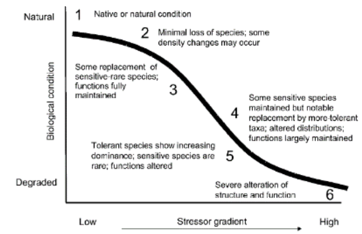
¹See the WDNR website for detailed information on invasive species: go to: dnr.wi.gov/, search "invasive plants"

Overall Disturbance: *Based on all the disturbance factors, what is the overall disturbance level at the site? Select only one.*	□ (1) Non-disturbed (Very Few alterations, none greater than low intensity) □ (2) Minimal (Small number of alterations of low intensity, none greater than moderate intensity) □ (3) Moderate (Alterations of mostly low and moderate intensity, no high intensity alterations) □ (4) Major (Many alterations, including at least one of high intensity) □ (5) Severe (Many alterations, including multiple high intensity ones)

Plant Community Condition Assessment: *Based on the vegetation survey, what is your best professional judgment of plant community condition in this Assessment Area? Select only one.*	□ (1) Natural structure & function of plant community maintained. □ (2) Minimal changes in structure & function. □ (3) Evident changes in structure & minimal changes in function. □ (4) Moderate changes in structure & minimal changes in function. □ (5) Major changes in structure & moderate changes in function. □ (6) Severe changes in structure & function.

General Comments:

TALU Disturbance Gradient



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WI P Standards for Surface Waters

Statewide Phosphorus Criteria

Rivers	Streams[1]	Reservoirs	Inland Lakes[2]	Great Lakes
100 µg/L	75 µg/L	• Not Stratified = 40 µg/L • Stratified = 30 µg/L	Ranges from 15-30 µg/L	• Lake Michigan = 7 µg/L • Lake Superior = 5 µg/L

[1]All unidirectional flowing waters not in NR 102.06(3)(a). Excludes Ephemeral Streams.
[2]Excludes wetlands and lakes less than 5 acres

Wetland "Water Quality" Elusive….

Wetlands

?

Modified from: Kirsch, K. and M. Diebel. 2018. *Wisconsin River Basin TMDL: TMDL Review and Report Overview.* Wisconsin Department of Natural Resources.

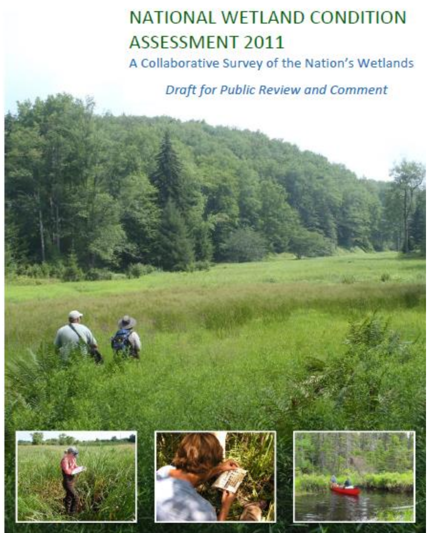
Wetland Assessment in Wisconsin

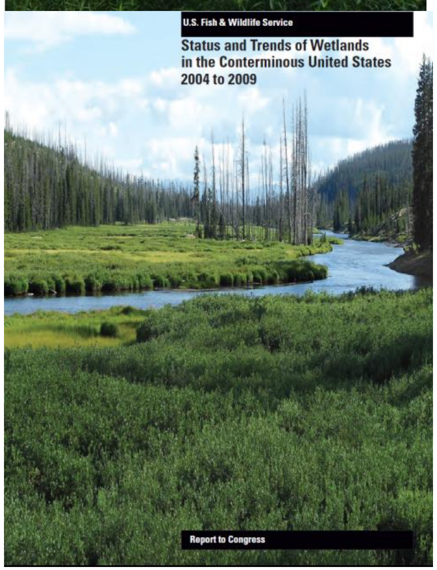
Problem:

Not all biotic and abiotic variables are present across 36 WI wetland types or even within a given type…
(BUT….NWCA had many variables to explore)

Exceptions:

National Wetland Condition Assessment (NWCA)

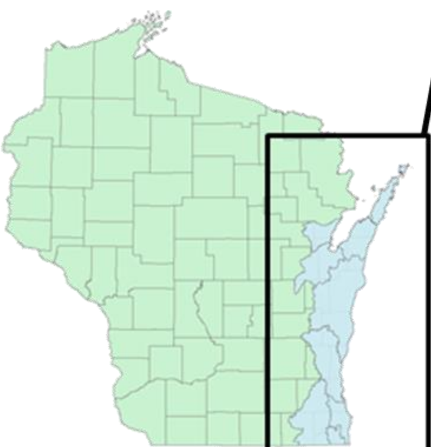


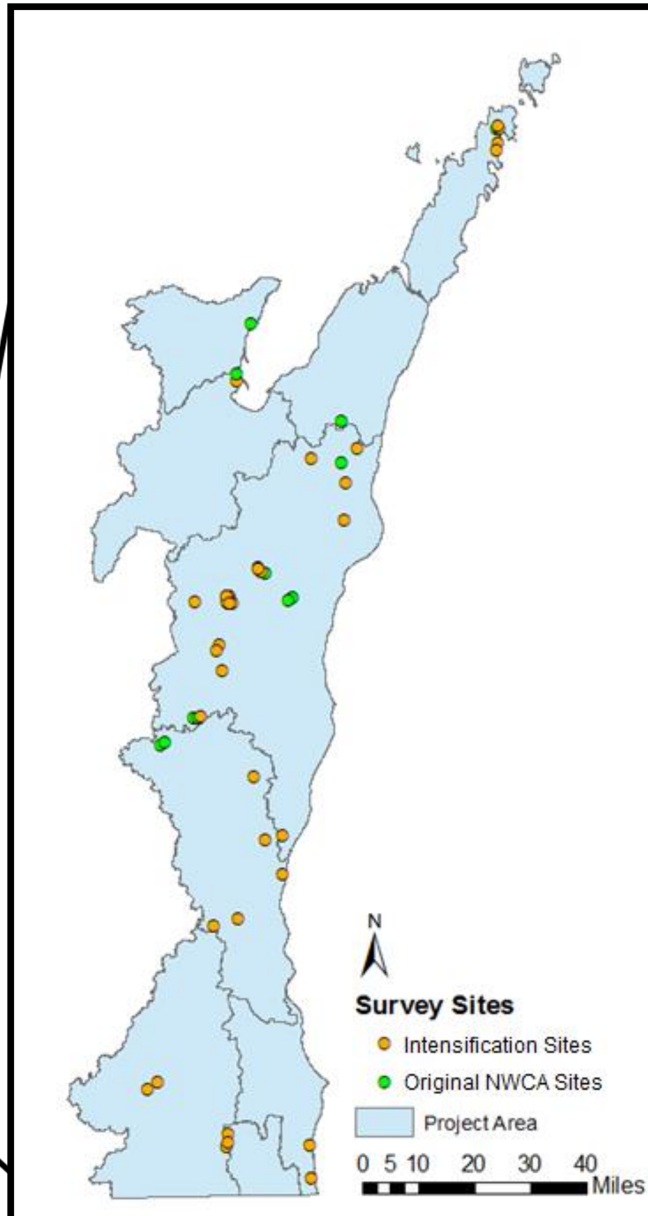


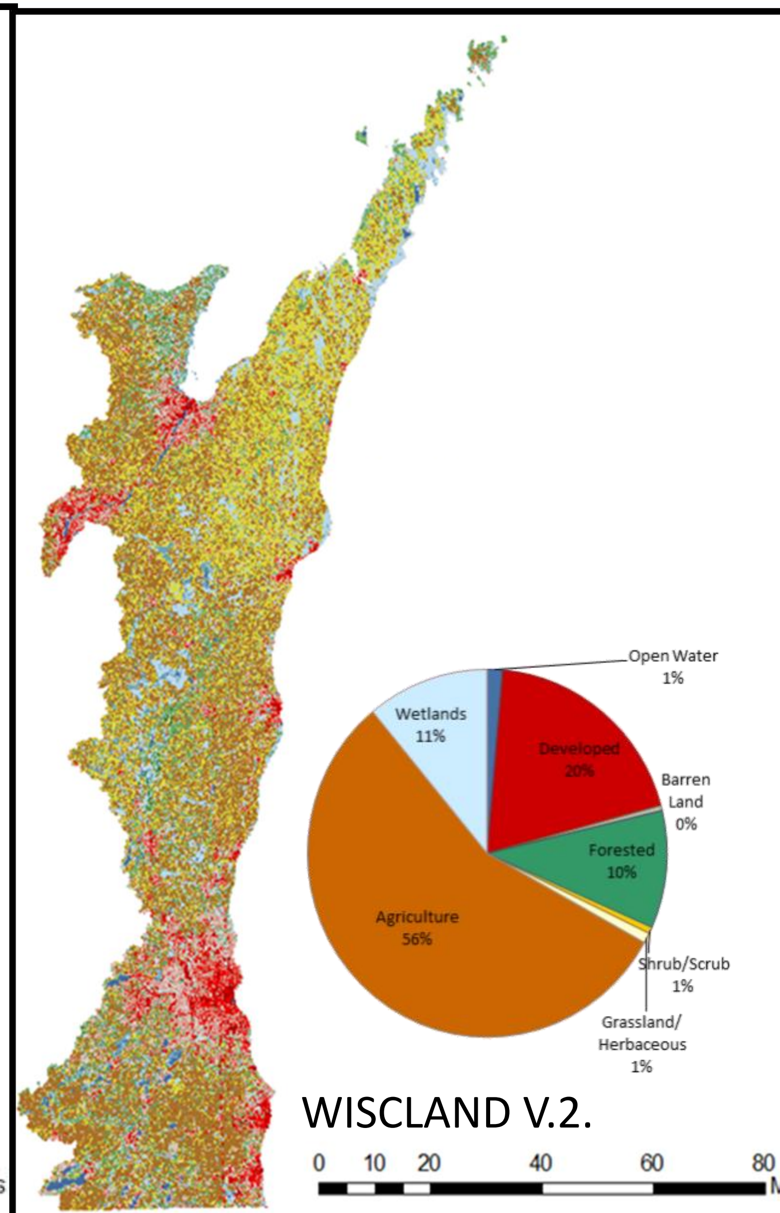
- **First national survey of wetland condition (2011)**
  - 2nd survey in 2016
- **Statistically-based, probabilistic, weighted sampling design** (2011 = 1137 sites)
  - Accounts for distribution and broad types of wetlands across nation and ecoregions
- **Paired with USFWS Wetland Status &Trends (NWI)**
  - Allowed for national and regional inference of condition

2011-2012 WI NWCA Intensification Area

- 50 Sites
- GRTS Selection
- All NWCA Field/Lab Protocols







Soil Types (WI Intensification)

"Mineral" "Mucky Modified Mineral"

MM

< 20 % Total Carbon

"Organic"

O

≥ 20 % Total Carbon

NWCA Vegetation Types

"Herbaceous"

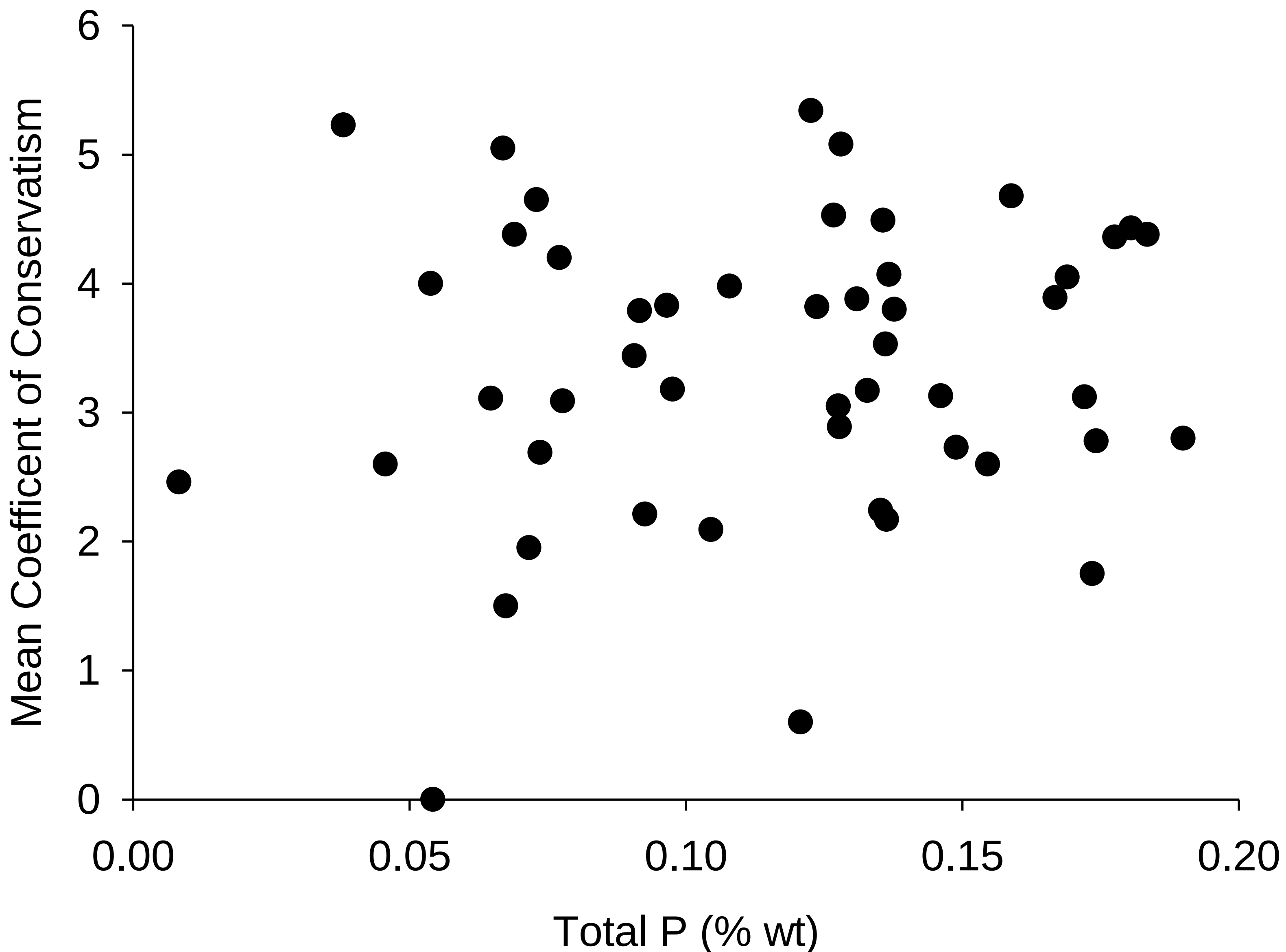
PH

"Woody"

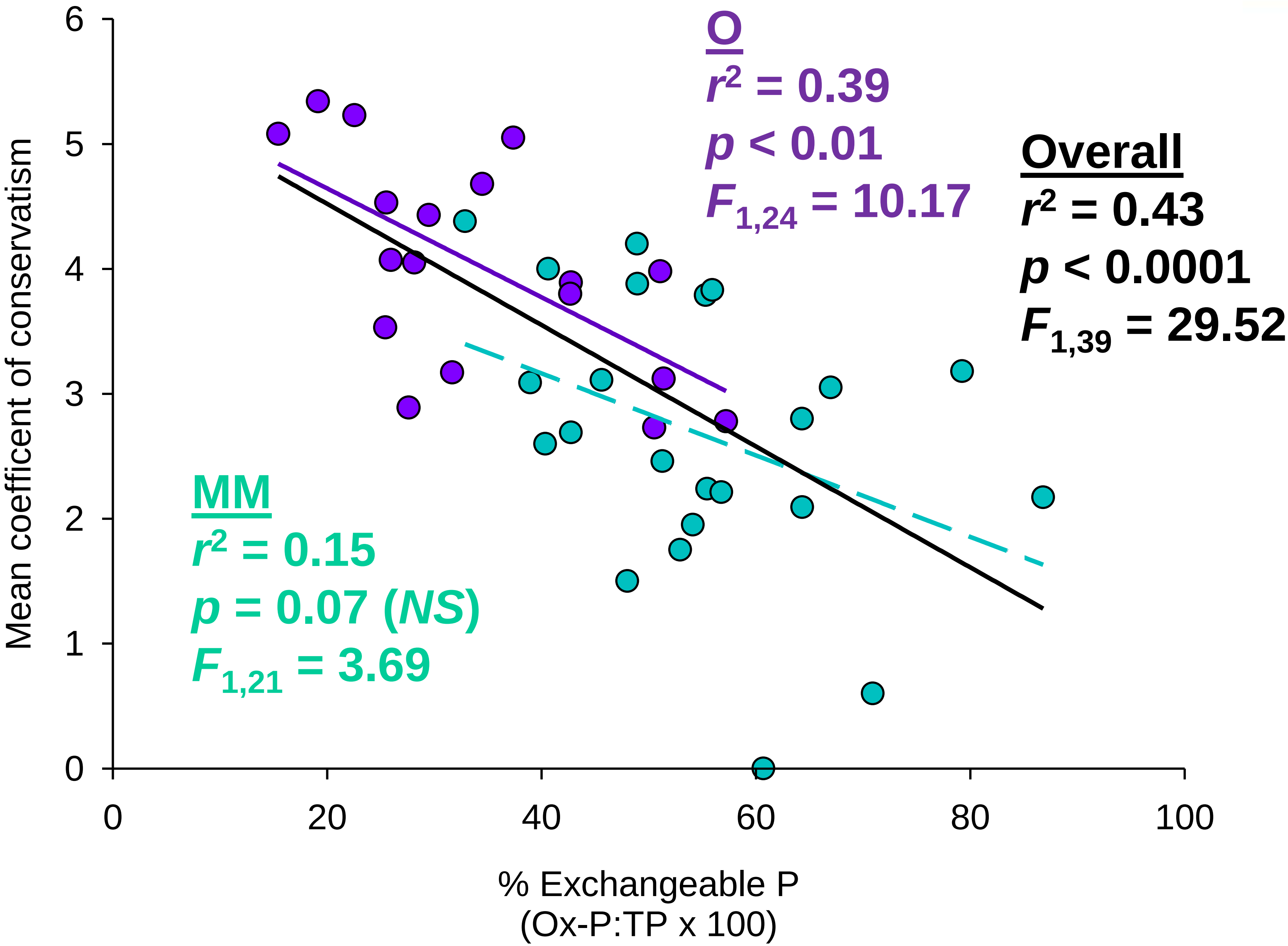
PW

Intensification WFQA - Soil P Relationships

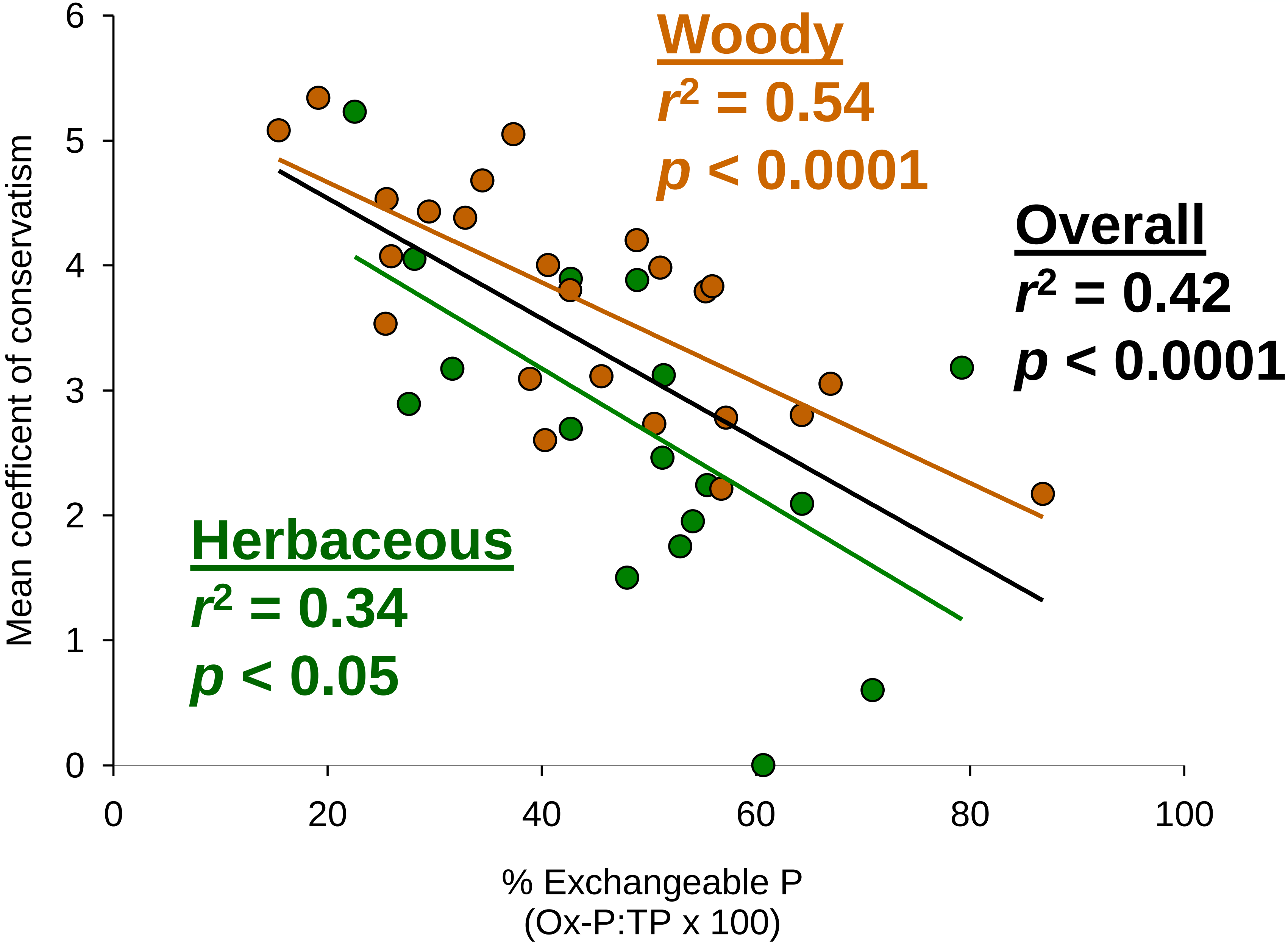
NWCA posited Soil TP as “Indicator of Stress”



Intensification WFQA - Soil P Relationships



Intensification WFQA - Soil P Relationships



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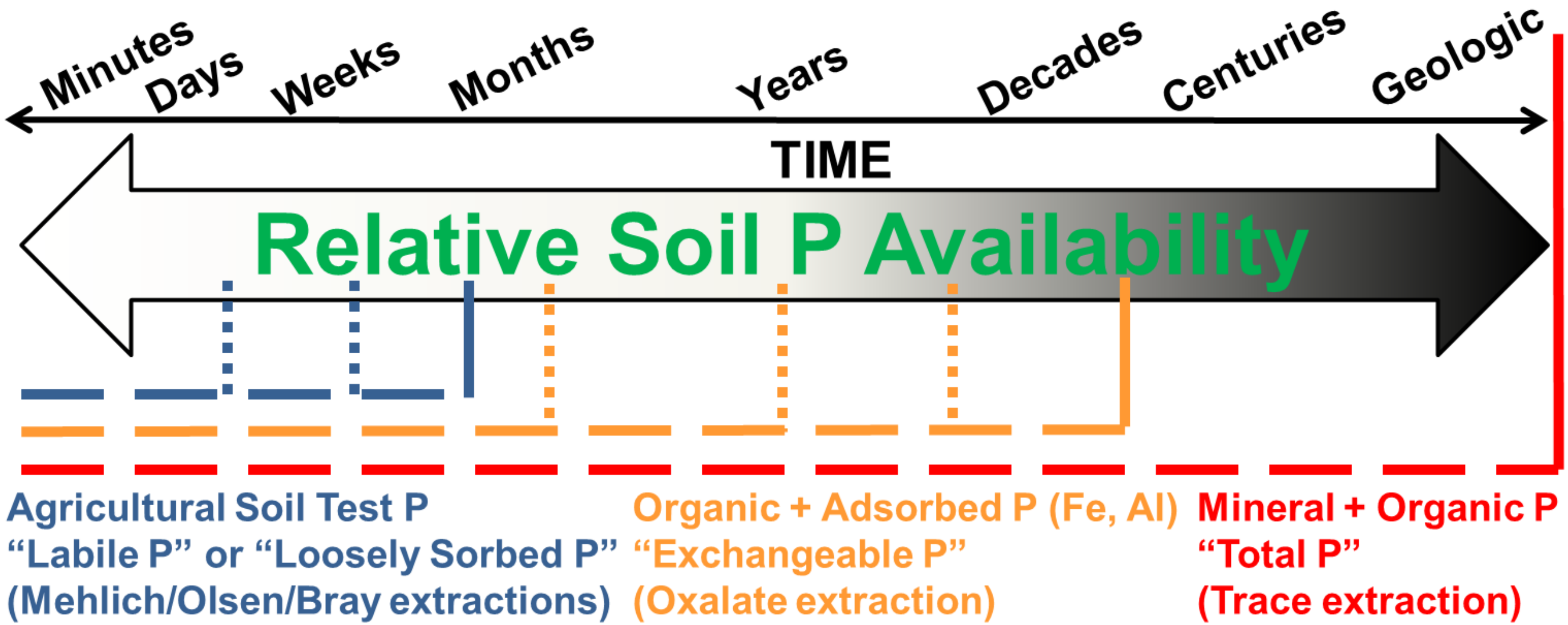
Conceptual P Framework



$$\frac{\text{Ox-P (Exchangeable P)}}{\text{Total P}} \times 100 = \%\ \text{Exchangeable P}$$

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Soil Phosphorus Storage Capacity (SPSC)

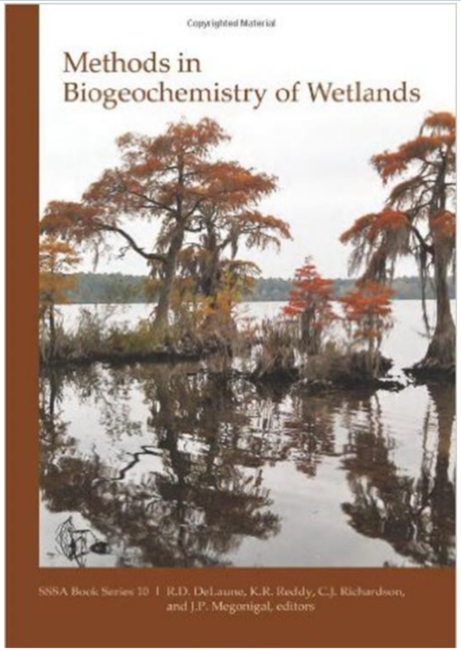
frontiers in ENVIRONMENTAL SCIENCE

MINI REVIEW ARTICLE
published: 10 April 2014
doi: 10.3389/fenvs.2014.00006

Soil phosphorus saturation ratio for risk assessment in land use systems

Vimala D. Nair *

Soil and Water Science Department, University of Florida, Gainesville, FL, USA



Soil P Storage Capacity =
f(Ox-P, Ox-Fe, Ox-Al)

$$SPSC = (\boxed{\text{Threshold PSR}} - \text{Soil PSR}) * [Fe + Al] * 31\ mg\ kg^{-1}$$

$$PSR = \frac{\text{Extractable} - P/31}{(\text{Extractable} - Fe/56) + (\text{Extractable} - Al/27)}$$

SPSC

***Only 1 Constant!* Remainder derived from site soil physicochemistry!**

- Accounts for:
  - Previous P loading, PM derived P, PM derived retention
- Predicts when PO4-P loss via runoff/leaching likely or estimates further soil PO4-P retention capacity

Wetlands (2015) 35:237–246
DOI 10.1007/s13157-014-0608-0

ORIGINAL RESEARCH

High Spatial and Fast Changes of Iron Redox State and Phosphorus Solubility in a Seasonally Flooded Temperate Wetland Soil

Michael Prem · Hans Christian Bruun Hansen · Walter Wenzel · Lisa Heiberg · Helle Sørensen · Ole Kragholm Borggaard

Journal of Environmental Quality ENVIRONMENTAL ISSUES

Phosphorus Legacy: Overcoming the Effects of Past Management Practices to Mitigate Future Water Quality Impairment

Andrew Sharpley,* Helen P. Jarvie, Anthony Buda, Linda May, Bryan Spears, and Peter Kleinman

Curr Pollution Rep (2017) 3:141–150
DOI 10.1007/s40726-017-0058-4

LAND POLLUTION (G HETTIARACHCHI, K SCHECKEL, AND G TOOR, SECTION EDITORS)

The Persistent Environmental Relevance of Soil Phosphorus Sorption Saturation

Peter J. A. Kleinman[1]

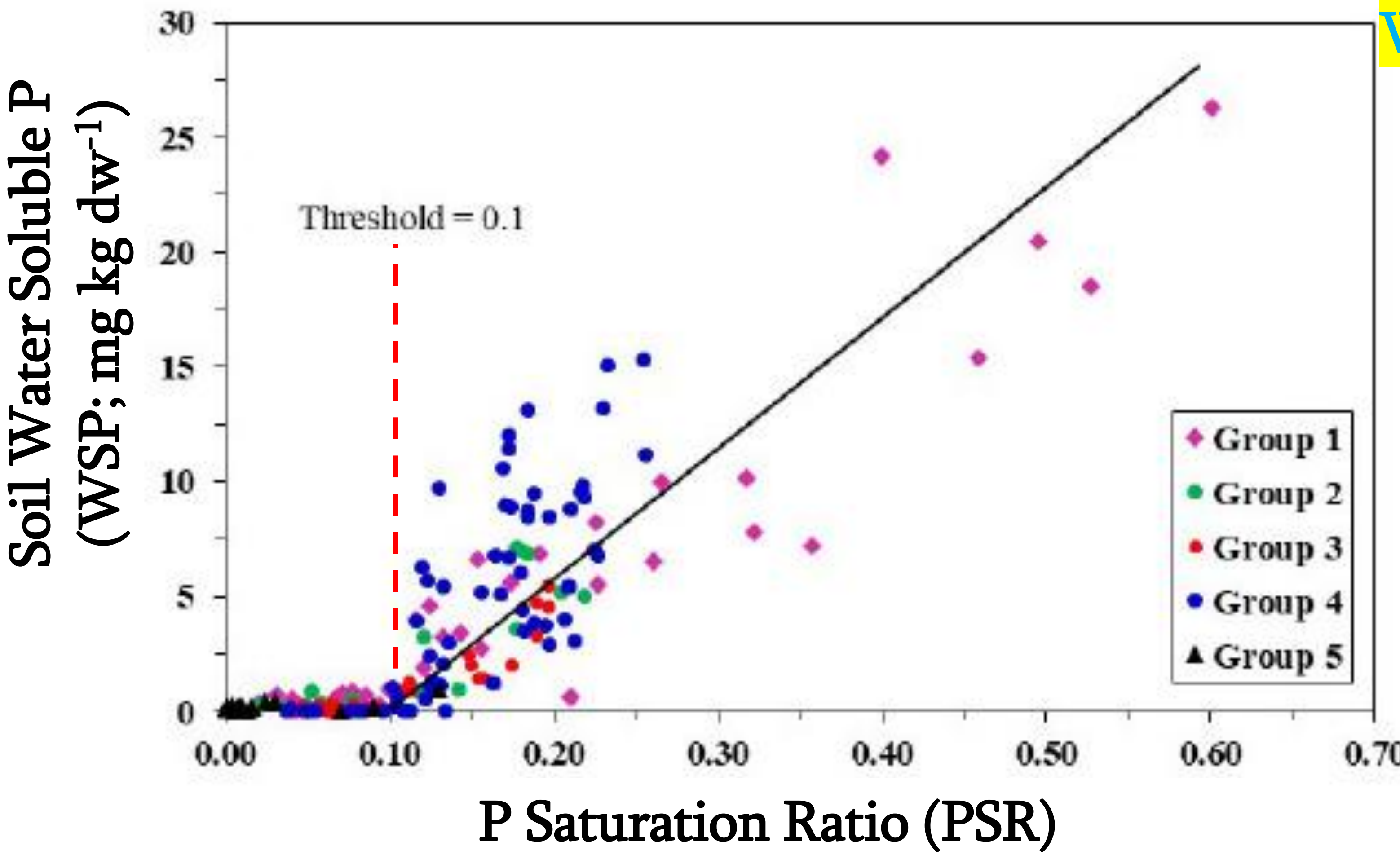
Threshold P Saturation Ratio (PSR)

Dari et al. 2018 *Agrosyst. Geosci. Environ.* 1:180028

Consistency of the Threshold Phosphorus Saturation Ratio across a Wide Geographic Range of Acid Soils

pH= 4.8 – 5.2

Biswanath Dari, Vimala D. Nair,* Andrew N. Sharpley, Peter Kleinman, Dorcas Franklin, and Willie G. Harris



WI Soil pH= 3.5 – 8.1 (μ = 6.2)

Only constant needed to calculate SPSC

Soil Phosphorus Storage Capacity (SPSC)

Key Assumption:
Threshold PSR = 0.1

SPSC is + = RETENTION

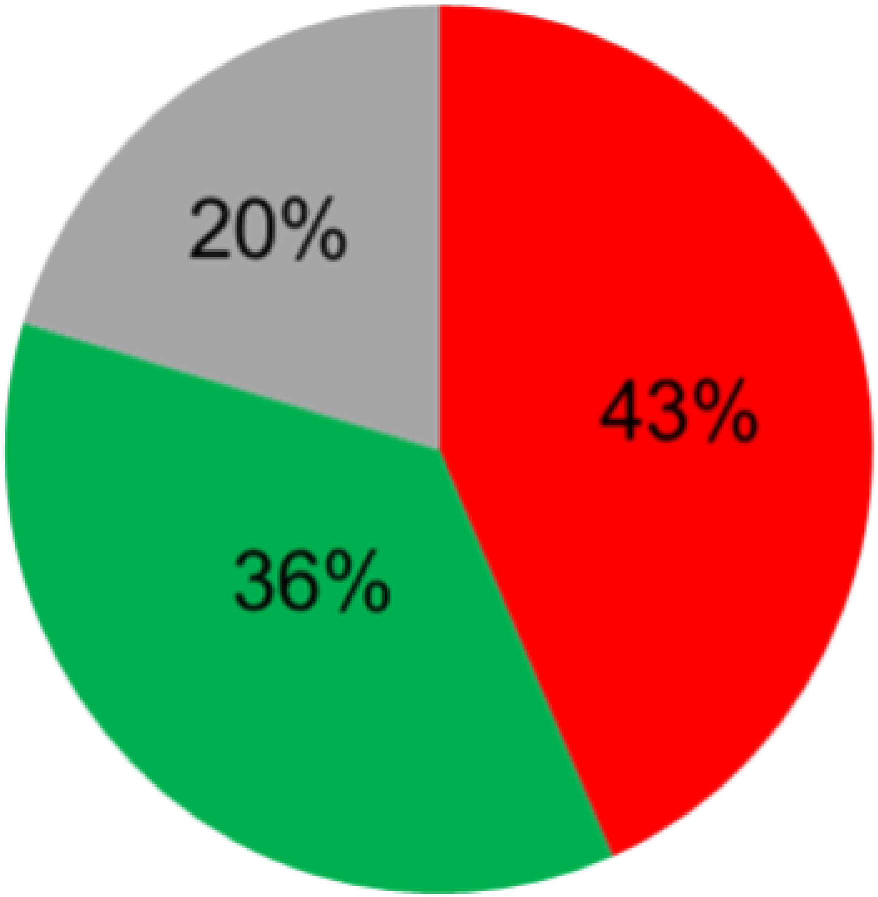
- Further DP storage likely
- Minimal DP release risk

UNKNOWN
(no lab data)

SPSC is − = LOSS

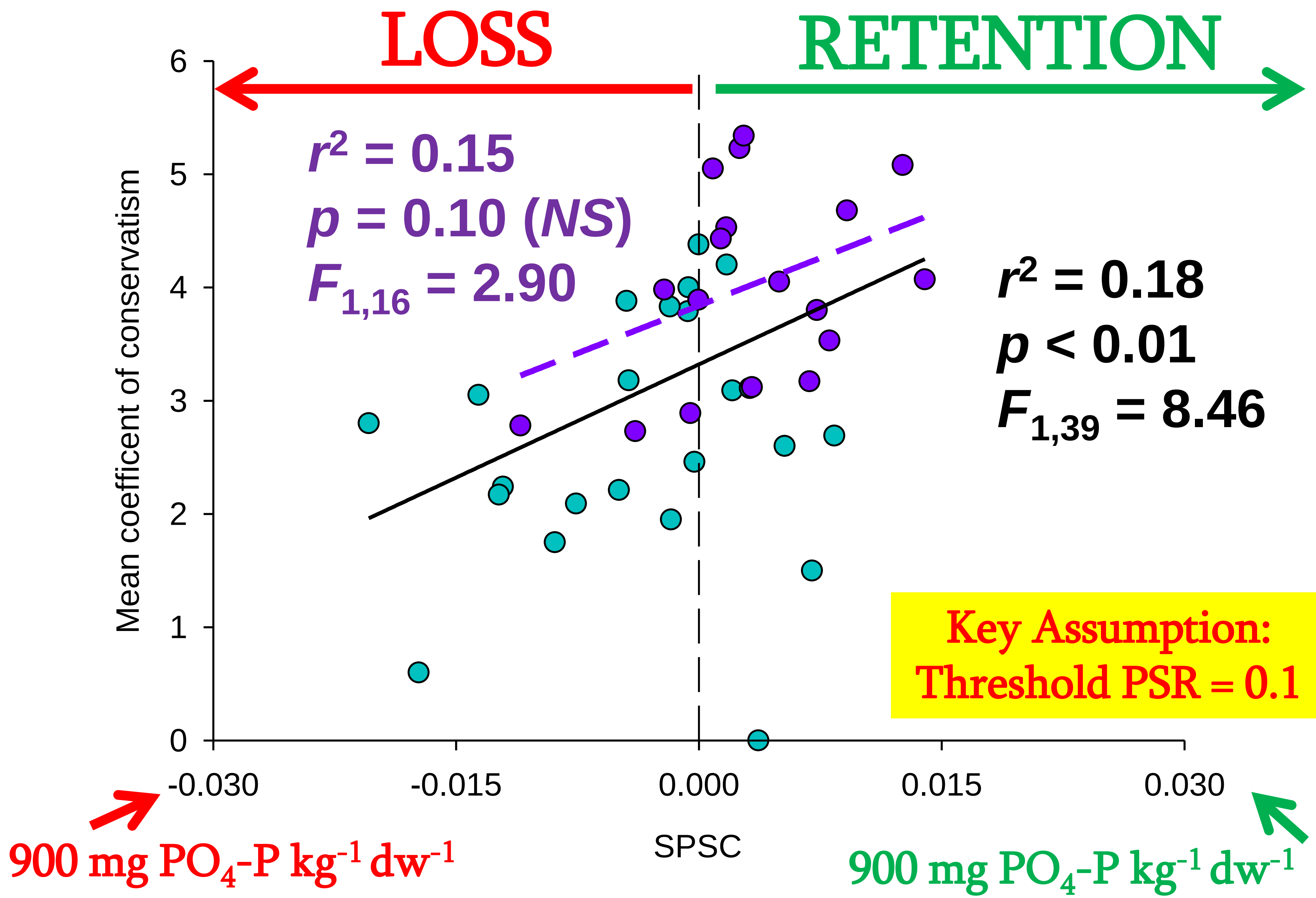
- DP storage met/exceeded
- Likely net DP release

Estimated % Wetland Area

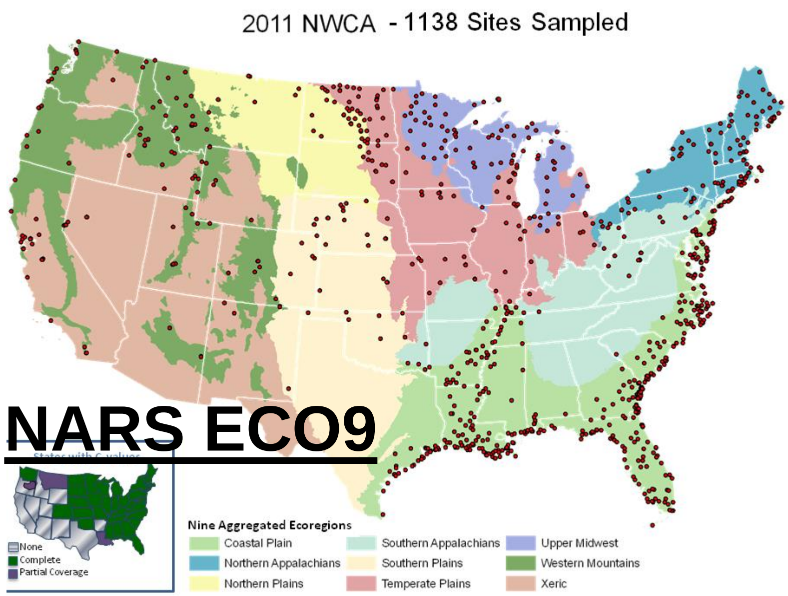


* ~425,000 Wetland Acres in Study Area

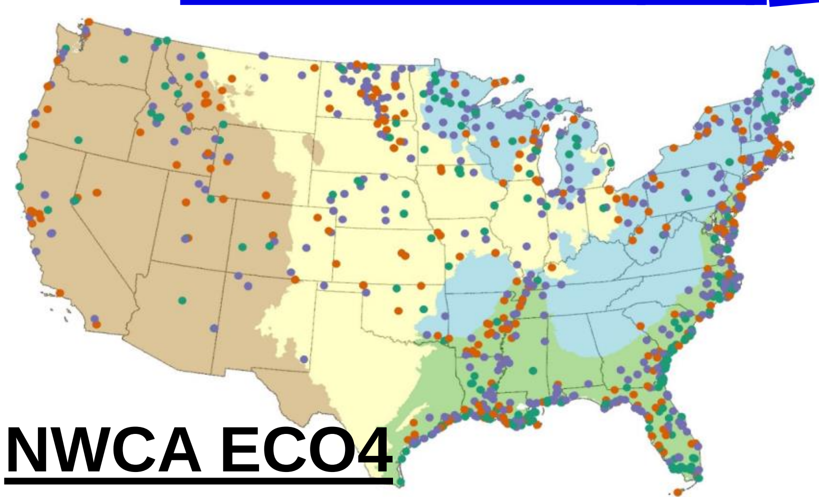
Mean C vs. SPSC



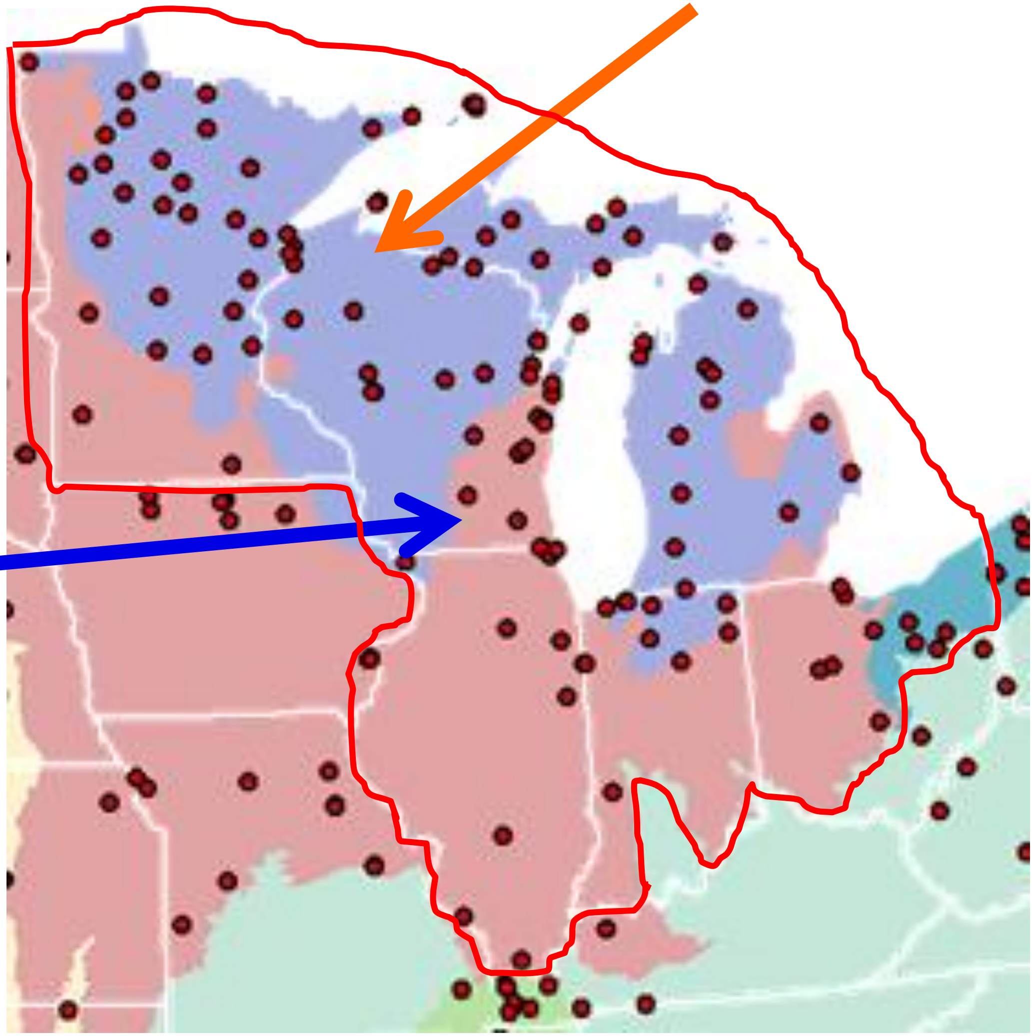
NWCA ECO4 Scale



NARS ECO9



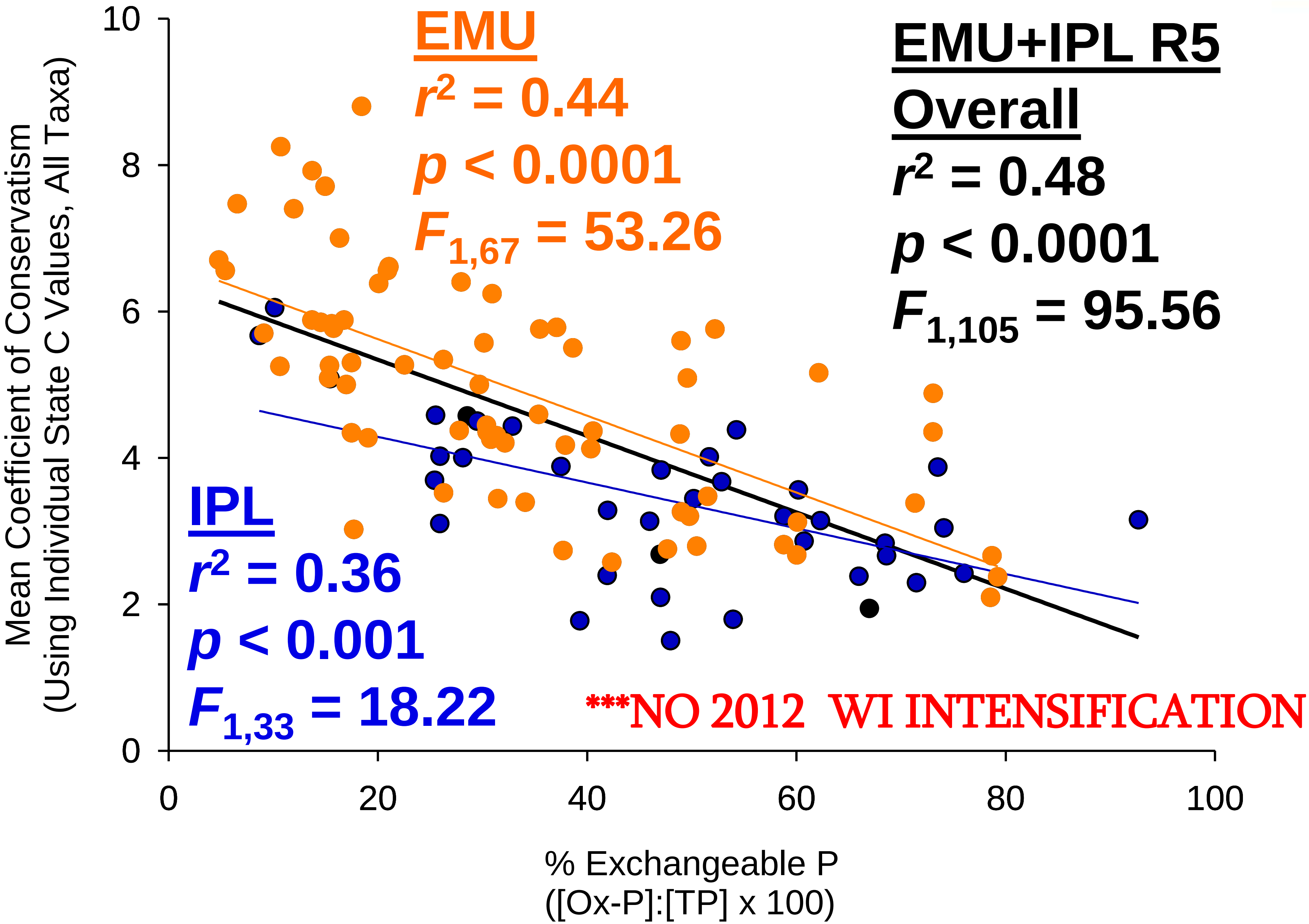
NWCA ECO4



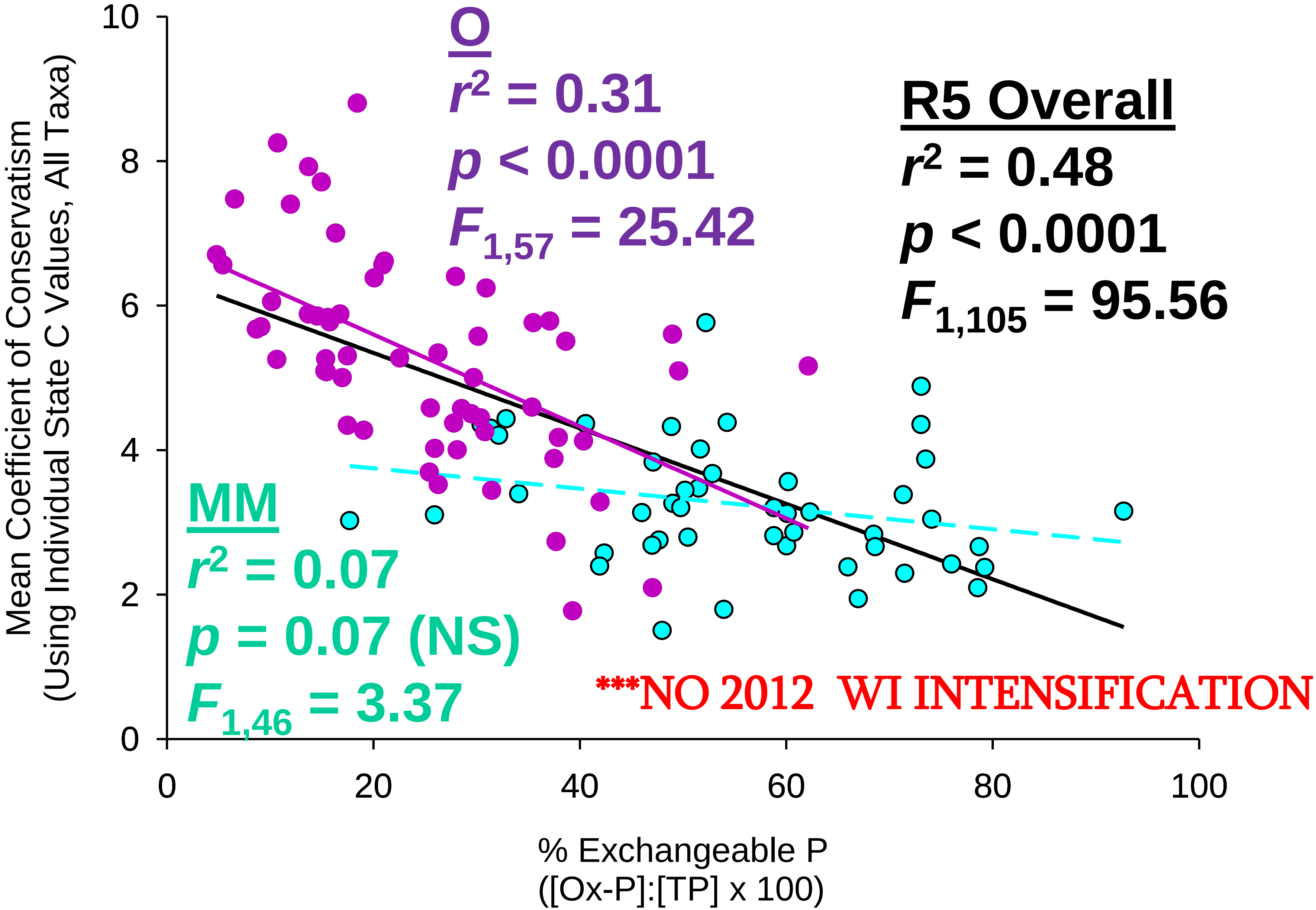
Eastern Mountains Upper Midwest (EMU)

Interior Plains (IPL)

All R5 NWCA11 Sites- NWCA ECO4

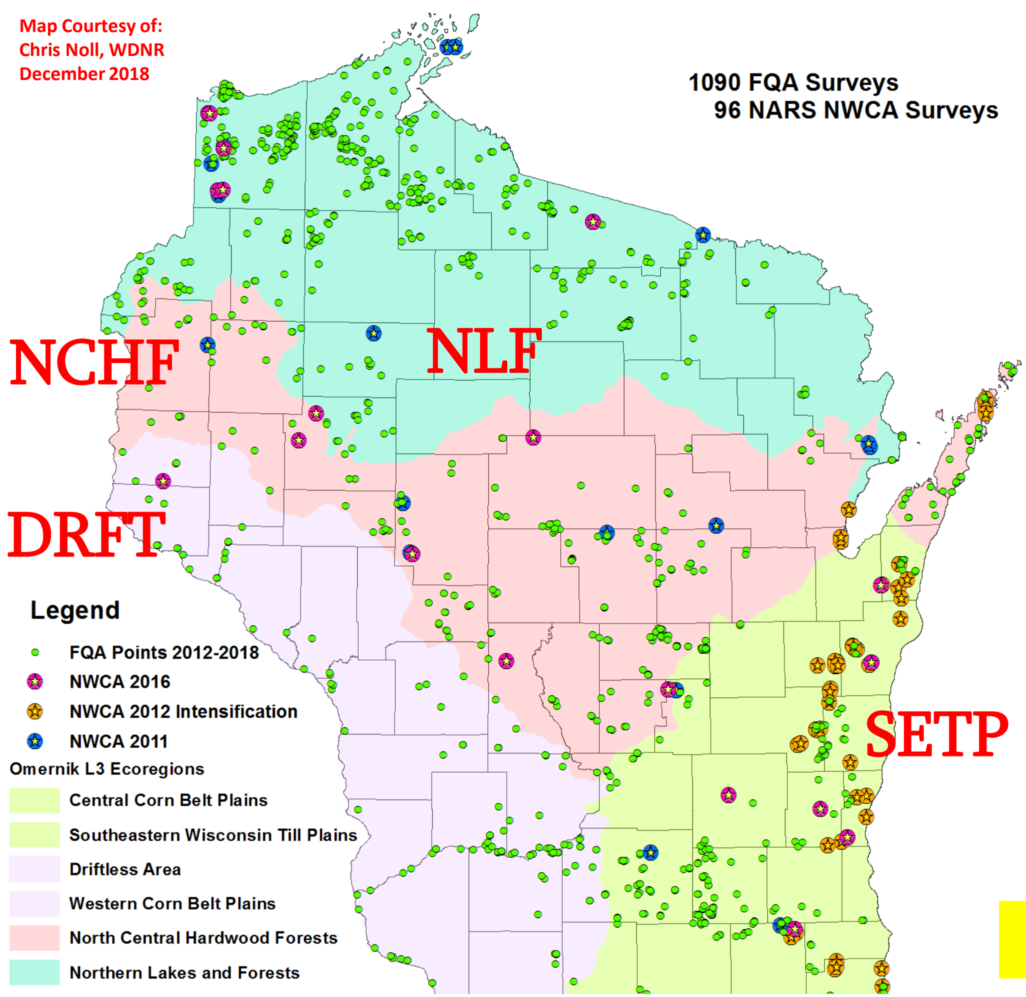


All R5 NWCA11 Sites- O vs MM



WFQA Benchmarks

DNR WQ Assessed Wetlands 2011 - 2018



Preliminary Ecoregional Benchmarks:

Survey Years	EPA Omernik III Ecoregion	# Sites	Status/Progress
2012 - 2014	Northern Lakes and Forests	509	Preliminary Benchmarks (LSRI, 2015)
2015	North Central Hardwood Forests	215	Report Complete; Forthcoming
2016 - 2018	Driftless Area	107+	Report Complete; Forthcoming
2016 - 2017	Southeastern Wisconsin Till Plains	185	Report Complete; Forthcoming
2018 – 2020	Statewide Final Benchmarks	1,090	Field Work Complete; Analysis Pending

70 Ecoregion x Veg Type WFQA BM sets!

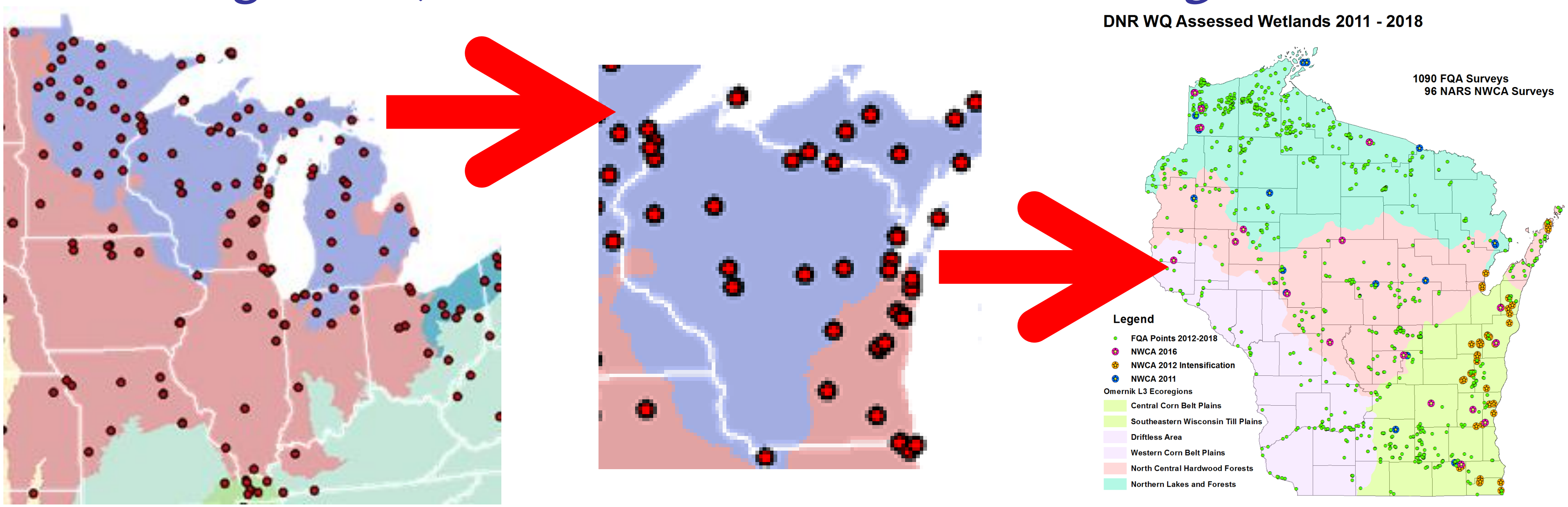
e.g. Mean C Benchmarks based on Overall Disturbance (Disturbance Factors Checklist)

	Preliminary Suggested Tiered Aquatic Life Use (TALU) Category				
	Least Disturbed			Most Disturbed	
	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Plant community type	"Excellent"	"Good"	"Fair"	"Poor"	"Very Poor"
Alder Thicket (AT)	>4.9	4.5 - 4.9	3.8 - 4.4	3.1 - 3.7	<3.1
Emergent Marsh (EM)	>5.2	4.8 - 5.2	3.4 - 4.7	1.7 - 3.3	<1.7

Scaling To Relevant Management Scales

Major Questions:

- Can we calibrate and test Threshold PSR/SPSC measurements at *statewide and ecoregional scales*? (Soil pH/PM Variation)
- How does PSR/SPSC relate to the standing surface water quality within wetlands?
- Are relationships among WFQA and SPSC related variables (i.e. % Exchangeable P) observable at *statewide and ecoregional scales*?



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Department of Natural Resources

FQA Benchmarks Soil Extension Project

NCSS
National Cooperative Soil Survey

SOILS
WISCONSIN COOPERATIVE SOILS PROGRAM

Wetland Vegetation Data and Evaluation for Ecological Site Descriptions (ESD's)

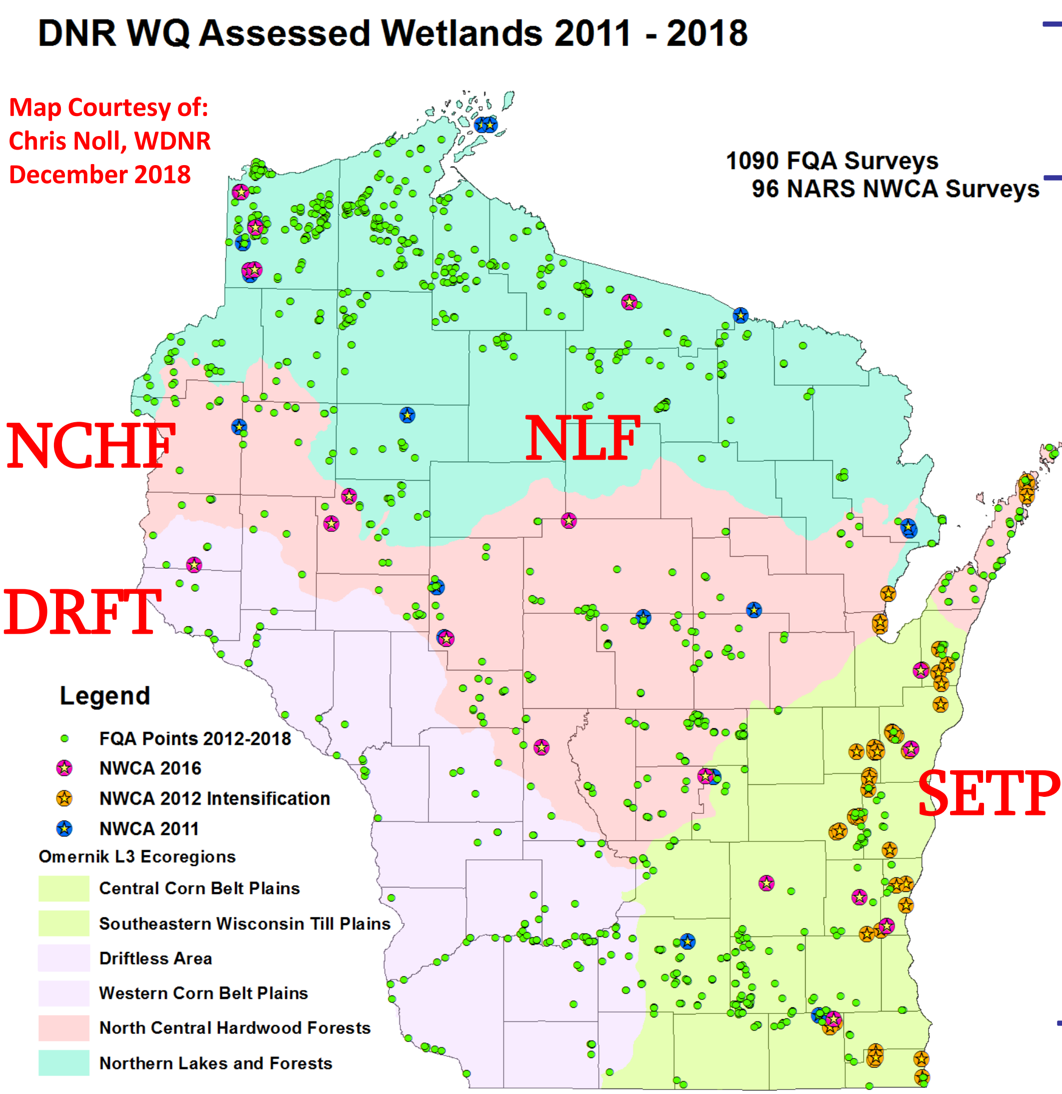
Soil Physicochemistry Lab Analyses and Technical Assistance
(National Soil Science Lab)

WISCONSIN
DEPT. OF NATURAL RESOURCES

Fieldwork Funding (R5 WPDGs)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

FQA Benchmarks Extension: Data Collected



~120 sites (NLF, NCHF)

-Soil Profile Description (50cm)

-Surface Soils (upper 15 cm)

-Water Chemistry (as available)

*TP, TDP, PO4, pH, Cond.

-Sediment Diatoms (120 sites)

227 Sites (SETP, DRFT)

-Surface Soils (upper 15cm)

1,090 Sites (All L3 ER)

-Floristic Quality

-Disturbance Factors Checklist

Original BM Study

WISCONSIN DNR Department of Natural Resources

Soil Material Types (This Study)

"Mineral" "Mucky Modified Mineral" "Organic"

MM O

NRCS Taxonomic Rules (% OC and % Clay) + Soil Profile Descriptions

WISCONSIN DNR Department of Natural Resources

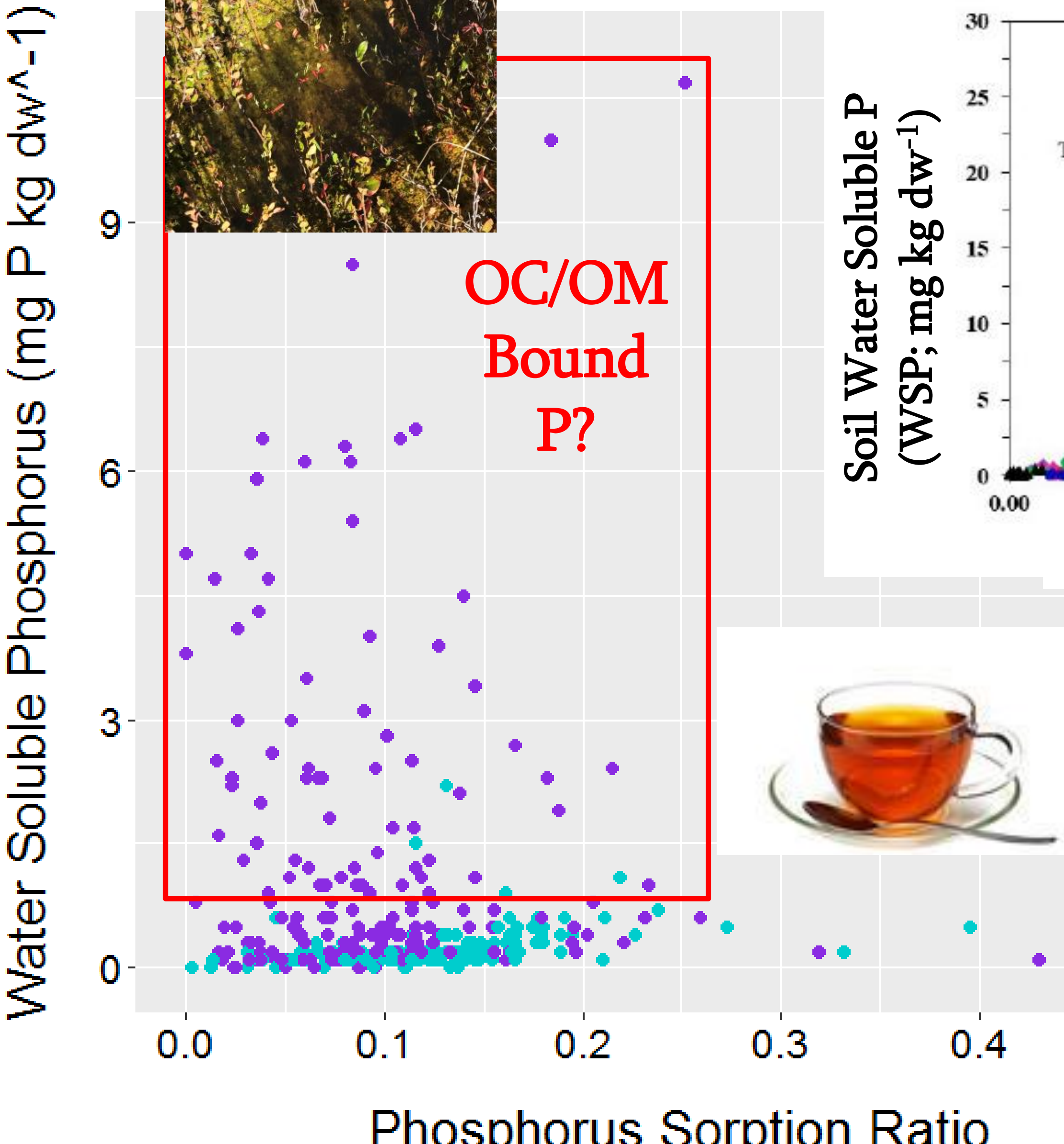
Broad Vegetation Types (This Study)

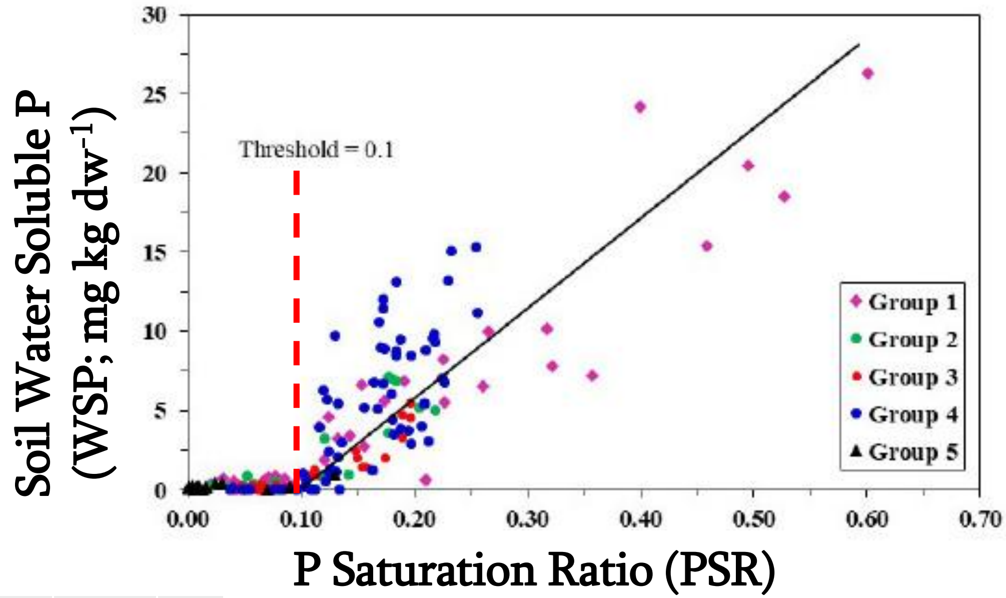
“H” “Herbaceous/Emergent”

“S” “Scrub-Shrub”

“F” “Forested”

PSR and SPSC Calibration





Issue: WSP Pore Size

KSSL = Whatman 47 (2.5 µm)

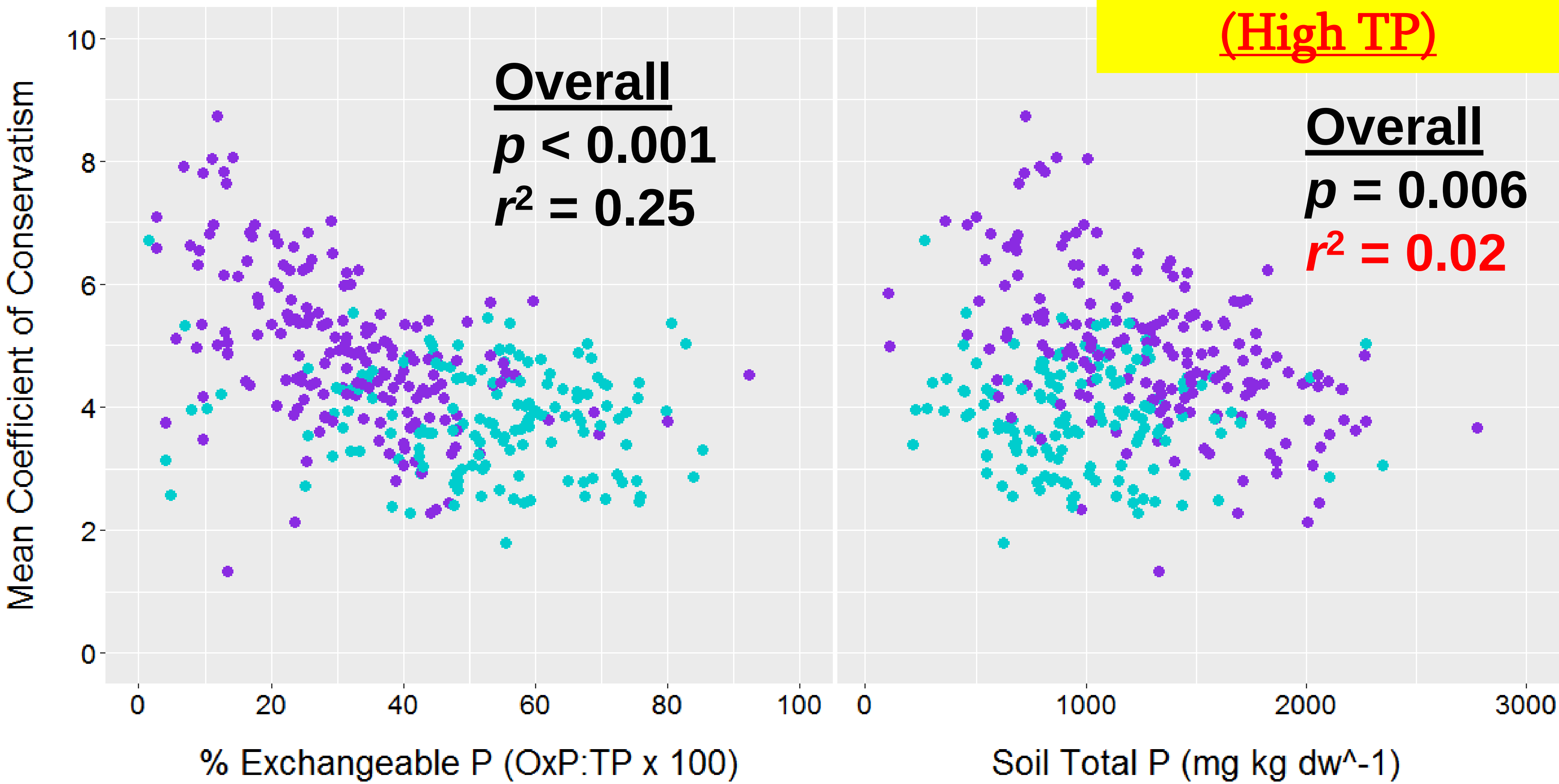
vs.

0.45 µm Standard

O samples

Mean C vs. Soil % Exchangeable/ Total P

*5 points not shown (High TP)



O
p < 0.001
*r*² = 0.24

MM
p = 0.14 (NS)
*r*² = 0.03

O
p < 0.001
*r*² = 0.07

MM
p = 0.04
*r*² = 0.03

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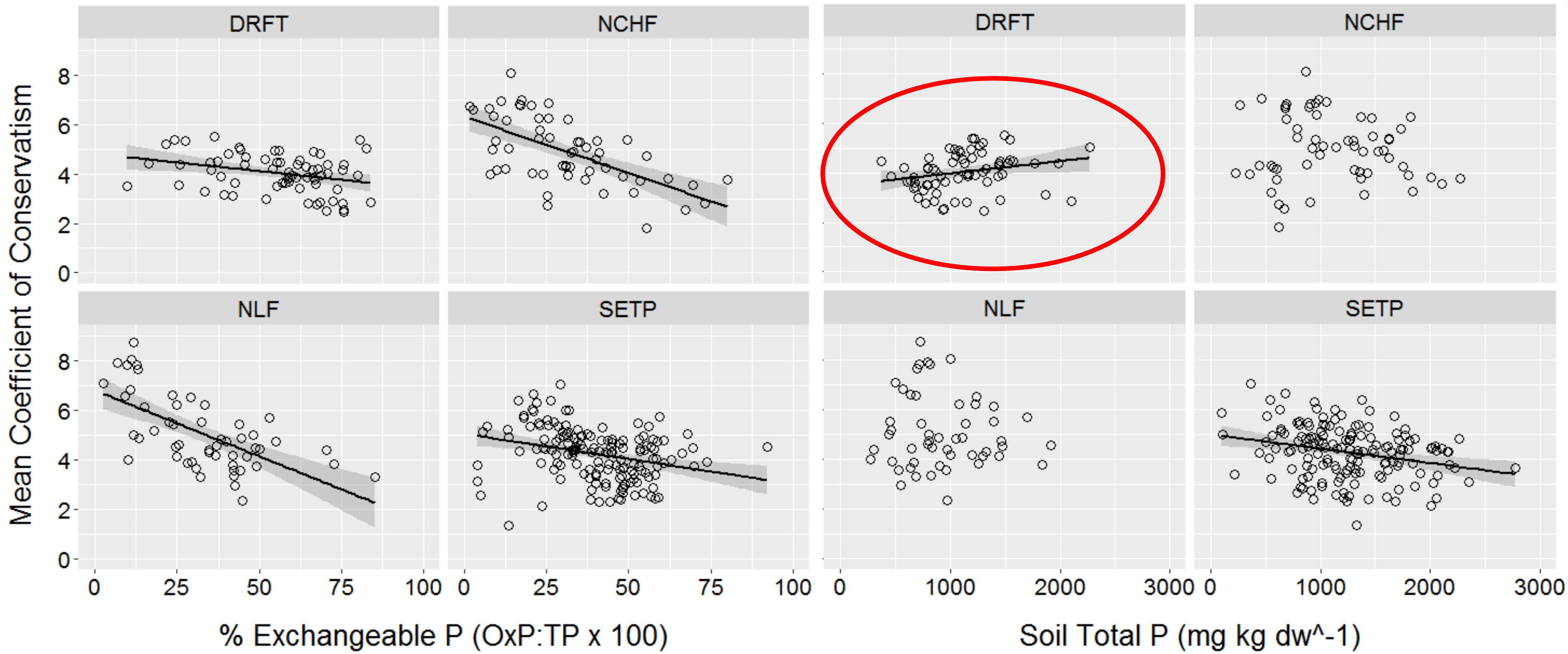
Mean C vs. Soil % Exchangeable/ Total P



Overall:

DRFT: $p = 0.009$, $r^2 = 0.10$

NCHF: $p < 0.001$, $r^2 = 0.38$

NLF: $p < 0.001$, $r^2 = 0.40$

SETP: $p < 0.001$, $r^2 = 0.09$

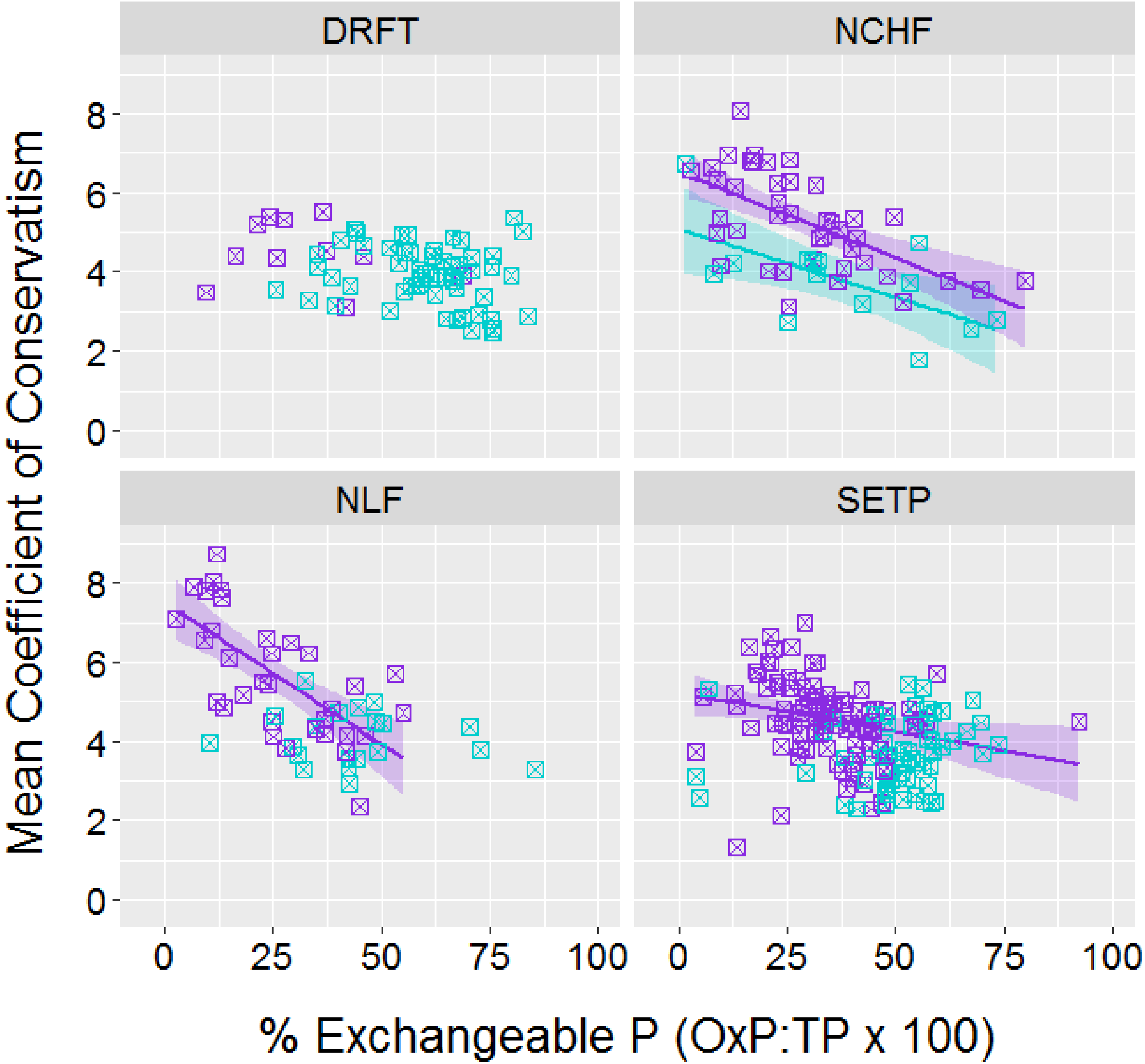
Overall:

DRFT: $p = 0.04$, $r^2 = 0.06$

NCHF: $p = 0.42$, $r^2 = 0.01$

NLF: $p = 0.21$, $r^2 = 0.03$

SETP: $p = 0.02$, $r^2 = 0.03$



DRFT

NS

NCHF

$p < 0.002$

$r^2 = 0.40$

$p < 0.001$

$r^2 = 0.37$

NLF

$p < 0.002$

$r^2 = 0.47$

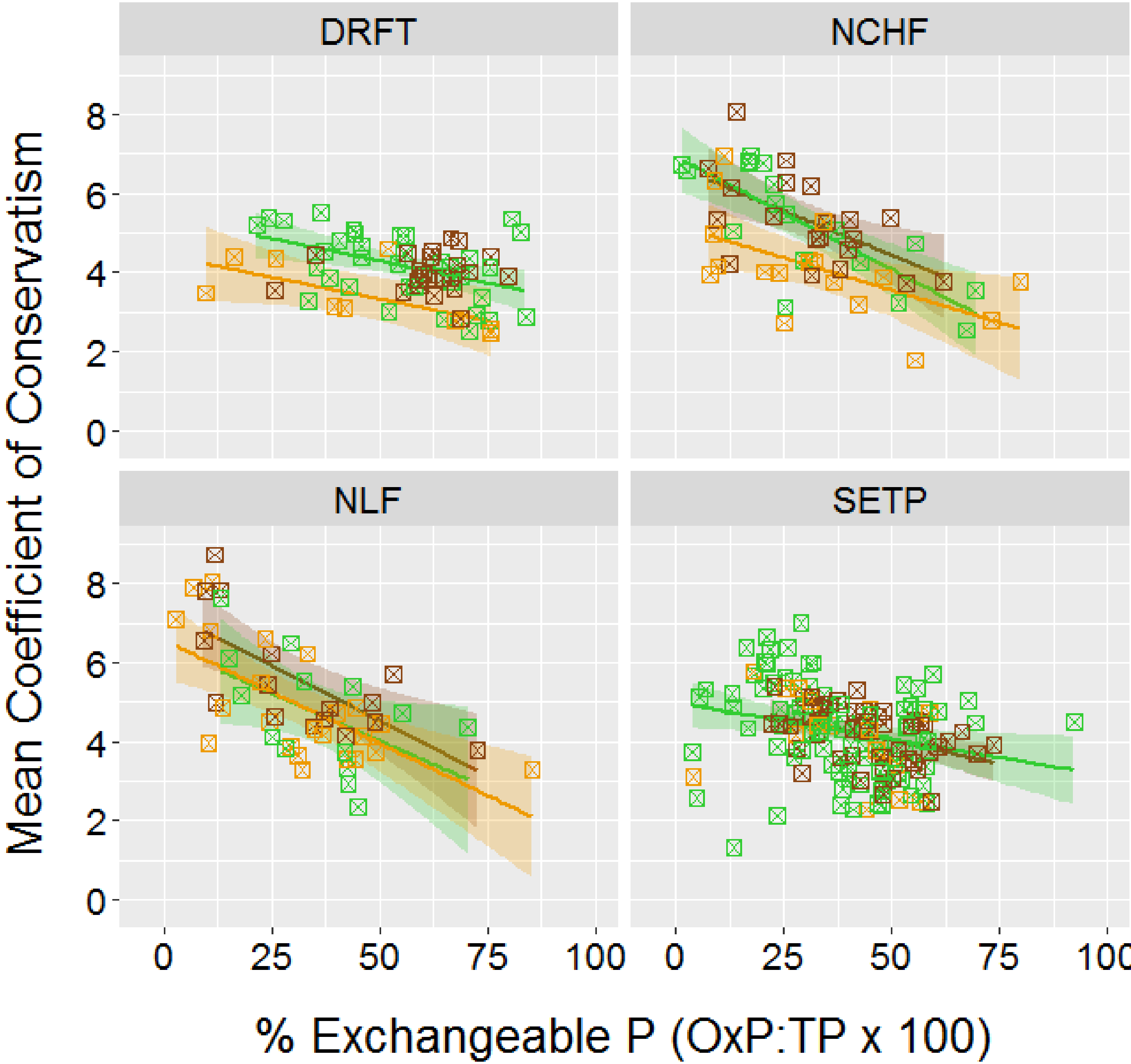
NS

SETP

$p = 0.002$

$r^2 = 0.06$

NS



DRFT

$p < 0.01$, $r^2 = 0.20$

$p = 0.053$, $r^2 = 0.43$

NS

NCHF

$p < 0.001$, $r^2 = 0.62$

$p = 0.01$, $r^2 = 0.33$

$p < 0.001$, $r^2 = 0.35$

NLF

$p = 0.054$, $r^2 = 0.28$

$p = 0.01$, $r^2 = 0.44$

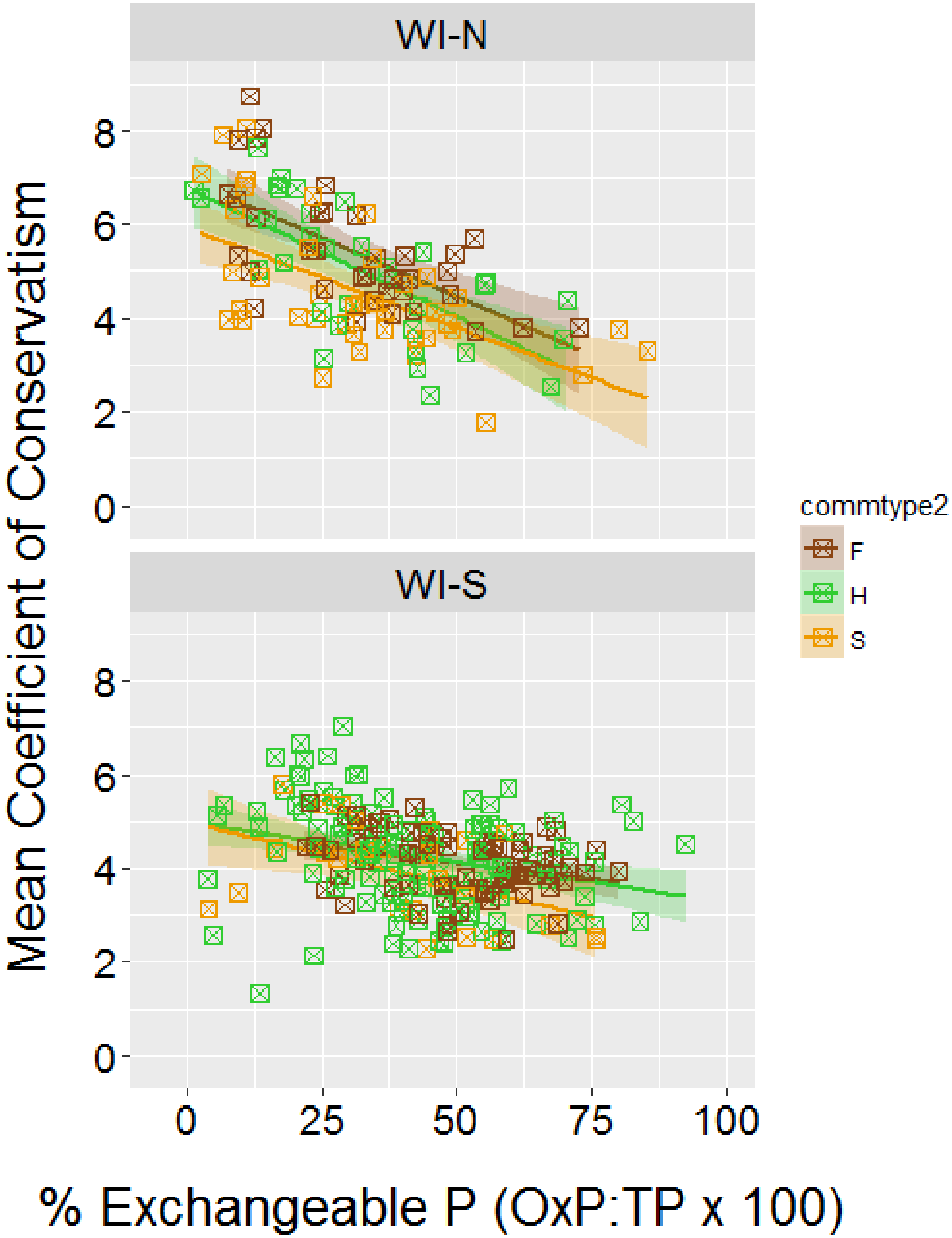
$p = 0.002$, $r^2 = 0.50$

SETP

$p = 0.02$, $r^2 = 0.07$

$p = 0.01$, $r^2 = 0.44$

$p = 0.003$, $r^2 = 0.17$



WI-N (NLF + NCHF)

p < 0.001, r^2 = 0.48

p < 0.001, r^2 = 0.36

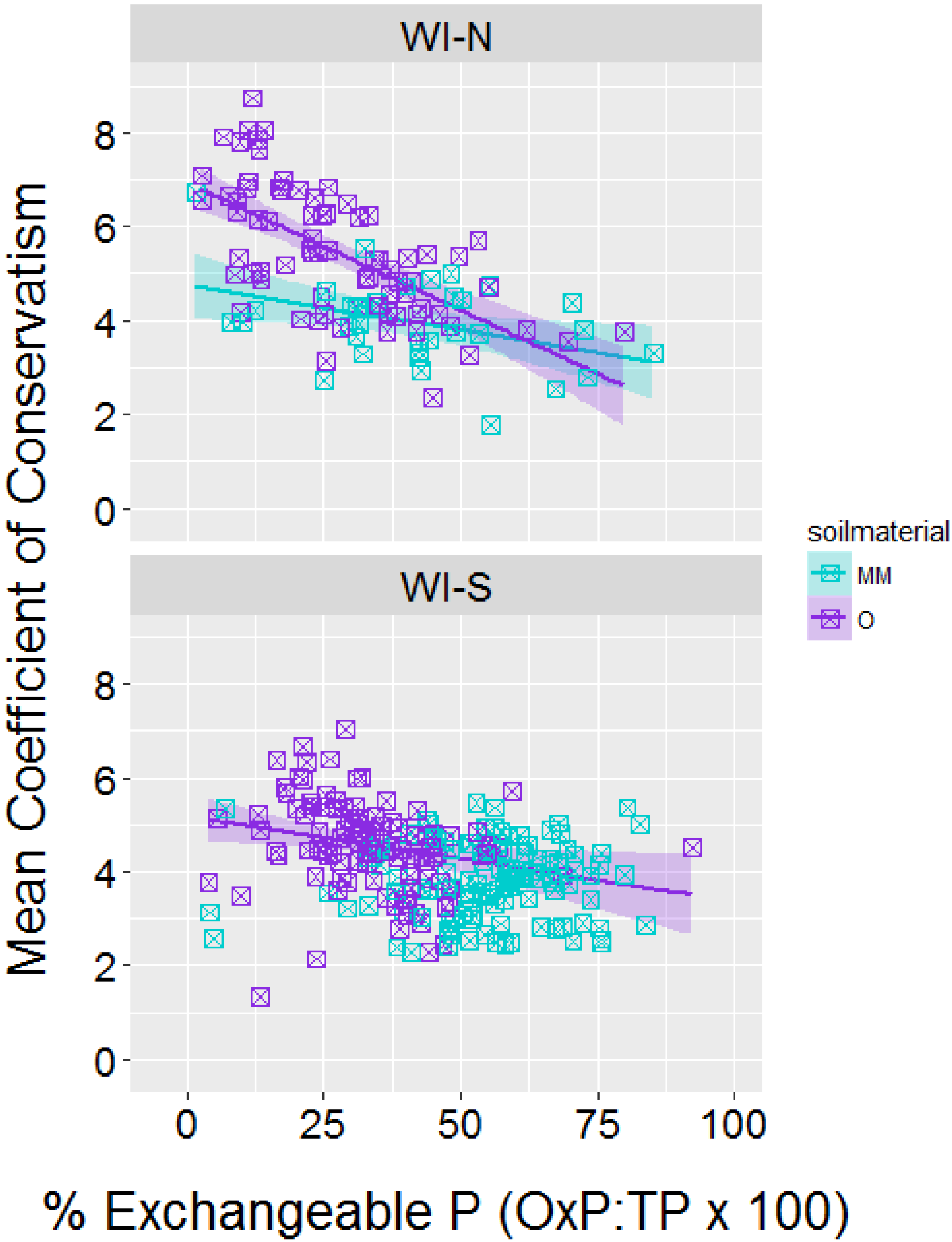
p < 0.001, r^2 = 0.42

WI-S (DRFT + SETP)

p = 0.001, r^2 = 0.08

p = 0.001, r^2 = 0.24

p < 0.003, r^2 = 0.10



WI-N (NLF + NCHF)

p = 0.02, r^2 = 0.16

p < 0.001, r^2 = 0.40

WI-S (DRFT + SETP)

p < 0.001, r^2 = 0.06

NS

Conclusions

- Calibration/validation of SPSC and related variables for wetlands?

?

But data suggesting "yes" pending further lab analyses

- Relationship of SPSC to standing water wetland chemistry and contribution to downstream waters?

?

- Relationships among WFQA and SPSC related variable relationships at statewide and ecoregional scales?

?

Generally YES! But more to explore

Take Home Lessons

11th NATIONAL MONITORING CONFERENCE

Working Together for Clean Water

March 25-29, 2019 Denver, Colorado

NWQMC

- The power of partnerships and value of data should never be underestimated! Never be afraid to reach out, even if unconventional and be persistent if you see and can clearly iterate potential collaborative gains!

NCSS National Cooperative Soil Survey

WISCONSIN DEPT. OF NATURAL RESOURCES

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

- Soils may be an excellent "integrator" variable for wetlands and other ecosystems—but we need to continually push and test our limits of knowledge beyond "tradition"
  - e.g. TP works for other systems, but is questionable at best for wetlands because many wetland soils naturally have high TP

Future "Horizons" ☺

- Numeric Wetland WQS based on vegetation AND soil physicochemistry?
- MORE DATA ANALYSES!
- Applications in NPS BMP's (Constructed treatment wetlands, buffers, stormwater features)
- Lake internal P loading predictions? TMDL model improvements?
- Alternative environmentally relevant Soil P Index?